DEPARTMENT OF THE AIR FORCE
59TH MEDICAL WING (AETC)
JOINT BASE SAN ANTONIO - LACKLAND TEXAS

21 FEB 2017

MEMORANDUM FOR SGOS
ATTN: LT COL ROSS A. SCHUMER

FROM: 59 MDW/SGVU

SUBJECT: Professional Presentation Approval

1. Your paper, entitled **Effect of Progressively Larger Lateral Column Lengthening Calcaneal Osteotomy on Radiographic Measurements of Foot Alignment** presented at/published to **American Academy of Orthopedic Surgeons Annual Meeting, CA, 16 March 2017** in accordance with MDWI 41-108, has been approved and assigned local file #**17100.**

2. Pertinent biographic information (name of author(s), title, etc.) has been entered into our computer file. Please advise us (by phone or mail) that your presentation was given. At that time, we will need the date (month, day and year) along with the location of your presentation. It is important to update this information so that we can provide quality support for you, your department, and the Medical Center commander. This information is used to document the scholarly activities of our professional staff and students, which is an essential component of Wilford Hall Ambulatory Surgical Center (WHASC) internship and residency programs.

3. Please know that if you are a Graduate Health Sciences Education student and your department has told you they cannot fund your publication, the 59th Clinical Research Division may pay for your basic journal publishing charges (to include costs for tables and black and white photos). We cannot pay for reprints. If you are 59 MDW staff member, we can forward your request for funds to the designated wing POC.

4. Congratulations, and thank you for your efforts and time. Your contributions are vital to the medical mission. We look forward to assisting you in your future publication/presentation efforts.

Linda Steel-Goodwin

LINDA STEEL-GOODWIN, Col, USAF, BSC
Director, Clinical Investigations & Research Support

PROCESSING OF PROFESSIONAL MEDICAL RESEARCH/TECHNICAL PUBLICATIONS/PRESENTATIONS

INSTRUCTIONS

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PROCESSING OF PROFESSIONAL MEDICAL RESEARCH/TECHNICAL PUBLICATIONS/PRESENTATIONS

1. TO: CLINICAL RESEARCH	2. FROM: (Author's Name, Rank, Grade, Office Symbol)	3. GME/GHSE STUDENT:	4. PROTOCOL NUMBER:
	Schumer, Ross A., Lt Col, 959 MDOS/SGOS	☐ YES ☒ NO	NA

5. PROTOCOL TITLE: (**NOTE:** For each new release of medical research or technical information as a publication/presentation, a new 59 MDW Form 3039 must be submitted for review and approval.)

Effect of Progressively Larger Lateral Column Lengthening Calcaneal Osteotomy on Radiographic Measurements of Foot Alignment

6. TITLE OF MATERIAL TO BE PUBLISHED OR PRESENTED:

Effect of Progressively Larger Lateral Column Lengthening Calcaneal Osteotomy on Radiographic Measurements of Foot Alignment

7. FUNDING RECEIVED FOR THIS STUDY? ☐ YES ☒ NO FUNDING SOURCE:

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American Academy of Orthopedic Surgeons Annual Meeting, CA, 16 Mar 2017

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Schumer, Ross, A. ross.a.schumer.mil@mail.mil	cell719-447-7061/pager513-3138

16. AUTHORSHIP AND CO-AUTHOR(S) List in the order they will appear in the manuscript.

LAST NAME, FIRST NAME AND M.I.	GRADE/RANK	SQUADRON/GROUP/OFFICE SYMBOL	INSTITUTION (If not 59 MDW)
a. Primary/Corresponding Author Schumer, Ross A.	Lt Col	959 MDOS/SGOS	
b. Anthony, Christopher	NA	NA	Univ of Iowa
c. Goetz, Jessica	NA	NA	Univ of Iowa
d. Phisitkul, Phinit	NA	NA	Univ of Iowa
e. Femino, John	NA	NA	Univ of Iowa

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Paper 489

Effect of Progressively Larger Lateral Column Lengthening Calcaneal Osteotomy on Radiographic Measurements of Foot Alignment

Christopher Anthony MD, Ross Schumer MD, Drew Kern, Adam Kruse, Jessica Goetz PhD, Phinit Phisitkul MD, John Femino MD

Abstract

Background: Lateral column lengthening is a common procedure for correcting Type IIB flat feet and has been shown to be clinically successful. The specific aims of this study were to establish a reliable Type IIB flat foot model, evaluate the effect of progressive lengthening on common radiographic measurements using simulated X-ray images from weight bearing computer tomography scans, and determine if overcorrection is possible using common lengths of distraction.

Methods: Eight intact (mid-tibial transection) adult cadaveric foot specimens were used to assess the effects of a ligament sectioning protocol for creation of Type IIB flat foot model and the subsequent effect of correction with 6, 8, and 10mm lengthening blocks. Each specimen was mounted in a custom loading jig that allowed for free tibial rotation and pronation with loading. Specimens were scanned under 100 pounds of axial load using a weightbearing CT scanner. Ligament sectioning was then performed using a protocol established during pilot work to create a reproducible Type IIB flat foot based on hindfoot valgus and midfoot abduction with divergence of the talus and calcaneus in the AP foot view. Key ligaments sectioned included the medial and plantar spring ligament up to coronoid fossa (sparing the lateral most fibers), the interosseous talo-calcaneal ligament (ITCL), and the cervical ligament. Each specimen was scanned under load with ligaments intact, in the flattened condition after ligament sectioning, and again after a lateral calcaneal lengthening osteotomy with 6, 8, and 10 mm lengthening blocks. Simulated AP and lateral radiographs were produced from the weightbearing CT images using custom code developed in Matlab. Three individuals measured naviculo-cuboid overlap, Meary's angle and AP talo-navicular coverage angle on each image in a blinded, randomized fashion. A period of training was used to establish consistent measurement techniques between individuals and interobserver agreement was assessed using intraclass correlation coefficients (ICCs).

Results: The interobserver agreement was excellent for the naviculo-cuboid overlap (ICC = 0.91), good for Meary's angle (ICC=0.81), and acceptable for the talo-navicular coverage angle (ICC=0.65). We report data on naviculo-cuboid overlap (Figure 1), Meary's angle (Figure 2) and AP talo-navicular coverage angle (Figure 3).

Conclusion: Sectioning of the cervical ligament, in addition to the spring ligament and ITCL, proved key to producing a type IIB flat foot in this cadaveric model. Lateral column lengthening restored the foot to a more normal anatomic position as defined by standard radiographic

measurements. A 10_mm lateral column lengthening tends to overcorrect all three measured radiographic measurements.

Introduction

Etiology of adult-acquired flatfoot deformity is most commonly described as collapse of the medial longitudinal arch with failure of the supporting soft tissue structures [1,2], most notably the posterior tibial tendon and spring ligament [3,4]. In the US, adult-acquired flatfoot deformity is thought to affect approximately 5 million people [2,5]. Lateral column lengthening is a common procedure for correcting Type IIB flat feet and has been shown to be clinically successful [6,7,8]. Various radiographic measures have been described to quantify the pathologic flatfoot. The lateral talo-first metatarsal angle (Meary's angle) [9], naviculo-cuboid overlap (NCO) [10], and talo-navicular coverage angle [10] are previously described measures that aid in the radiographic assessment of flatfoot deformity.

The specific aims of this study were to establish a reliable Type IIB flat foot model, to evaluate the effect of progressive lengthening on common radiographic measurements using images from weight bearing scans, and to determine if overcorrection is possible using common lengths of distraction.

Methods

Cadaver Experimentation

Eight intact (mid-tibial transection) adult cadaveric foot specimens without obvious deformity or evidence of previous surgery were used to assess the effects of a ligament sectioning protocol for creation of a Type IIB flat foot model and the subsequent effect of correction with 6, 8, and 10mm lengthening blocks. To prepare for testing, each cadaveric specimen was ~~cut~~ transected 30 cm proximal to the ankle joint. An 8 cm span of soft tissue adjacent to the saw cut was removed in preparation for potting the proximal tibia and fibula in a cylindrical polymethylmethacrylate bone cement block for interfacing with the pot on a custom loading frame.

Metallic beads were subsequently placed in the talus, calcaneus, navicular, and cuboid for future analysis. During dissection for bead placement, care was taken to preserve the following structures: Deltoid ligament (deep and superficial) including the anterior band, the spring ligament, bifurcate ligament, anterior talofibular ligament, calcaneal fibular ligament, and medial two inferior extensor retinaculum roots.

Specimens were frozen to -20°C for storage and then thawed for 24 hours at room temperature prior to biomechanical testing. For all images acquired in this work, the specimen was loaded in a standing weight bearing position using a custom frame and stacking weights. Each specimen was positioned in the frame for scanning with the foot placed on a horizontal low-friction polymer (Delrin) sheet. A vertical post embedded in the polymer sheet was positioned in the web space between the first and second toes to prevent the foot from displacing anteriorly during loading. The foot was otherwise unconstrained and allowed to naturally

pronate under load. The potted proximal tibia/fibula were held in a cylindrical clamp allowed to translate freely in the anterior/posterior and medial/lateral directions through support provided by two pairs of perpendicularly oriented bearing slides.

A 450 N (100 pound) static load was applied to the proximal tibia/fibula using stacking weights added to a vertical post extending from the proximal specimen clamp and offset anteriorly. This was chosen to simulate the normal weight bearing load of a 900 N patient in double leg stance as would be the case for weight bearing xrays. Once the weight was added to the frame and the cadaveric specimen settled in its natural weightbearing position, locking collars on the bearings were locked to stabilize the construct for CT scanning. All specimens were imaged using a weightbearing CT scanner (PedCAT, CurveBeam).

Specimens were first imaged intact to establish baseline radiographic measurements. The specimen was then removed from the loading frame and a Type IIB flat foot was created using a protocol established during pilot work based on hindfoot valgus and midfoot abduction with divergence of the talus and calcaneus in the AP foot view. Key ligaments sectioned included the medial and plantar spring ligament up to coronoid fossa (sparing the lateral most fibers), the interosseous talo-calcaneal ligament (ITCL), and the cervical ligament. Care was taken to preserve the tibio-calcaneal portion of the superficial and deep deltoid ligament medially and the bifurcate ligament laterally. The specimens were then remounted in the loading frame, the same 450 N load was applied, and a CT scan was acquired in this flatfoot condition.

Specimens were again removed from the loading frame for a surgical flatfoot reconstruction using a modified single cut lateral calcaneal lengthening procedure. The location of the osteotomy was based on the anterior edge of the posterior facet [11]. The peroneal tendons were elevated from the calcaneus and an oscillating saw was used to perform the osteotomy. The specimens were remounted. Three progressive levels of lengthening (6 mm, 8 mm, and 10 mm) of the lateral column were performed using a hard rectangular polyurethane foam spacer inserted into the lateral calcaneal osteotomy until the surface was flush with the cortical bone surface. Weightbearing CT scans were acquired after each progressive lengthening.

Flatfoot Measurement

The resultant CT scan DICOM images were used to create simulated AP and lateral weightbearing radiographs using custom code developed in Matlab (The Mathworks, Natick MA). Prior to creation of simulated radiographs, the geometry of the foot was segmented from the CT volume, and all background information was removed in attempts to reduce the influence of beam hardening artifact caused by the loading frame and implanted beads on the resulting images. The simulated radiographs were created by projecting rays through the CT volume such that each ray corresponded to a pixel on a virtual digital radiography (DR) detector. The positioning of the CT volume and the virtual DR system rays were adjusted to replicate the parameters of clinical A/P and lateral weightbearing radiographs.

Three standard radiographic measures of foot alignment were then performed on the resulting simulated digital radiographs. In order to standardize the measurement technique, a custom ImageJ plugin was written to guide each analyst through consistent anatomic landmark detection from which naviculo-cuboid overlap, Meary's angle, and AP talo-navicular coverage angle were calculated.

For the naviculo-cuboid overlap (NCO) measurement, the user was prompted to select the superior extent of the cuboid (), the inferior extent of the cuboid (), and the inferior extent of

the navicular () from the lateral simulated radiograph. (Figure 1a) NCO was computed as the vertical height of the cuboid () divided by the vertical distance between the top of the cuboid and the bottom of the navicular (). The value of this measurement ranges from 0 (no overlap of the navicular and cuboid) to 1 (complete overlap between the navicular and cuboid).

For the Meary's angle (MA) measurement, the user was prompted to draw lines spanning the proximal and distal metadiaphyseal junctions of the first metatarsal (and , respectively), a line spanning the articular surface of the talar head () and a line from the lateral process of the talus to the center of the talar dome () on the lateral simulated radiograph. (Figure 1b) The axis of the first metatarsal was computed by creating a line through the midpoints of the and the measurements. The axis of the talus was found in similar fashion by creating a line through the midpoints of the and measurements. MA was reported as the angle between these two axes with apex dorsal indicated by positive values and apex plantar indicated by negative values.

For calculating talo-navicular coverage (TNC), the user was prompted to select a line spanning the articular surface of the talar head () and a line spanning the articular surface of the navicular () on the simulated AP radiograph. (Figure 1c) TNC was calculated as the angle between the and lines. Positive values indicated a more abducted or flatter foot (Sangeorzan etal FootAnkle 1993 (14:3, 136-141)).

All three measurements were performed by three reviewers on all simulated radiographs. Measurements were performed in a randomized and blinded fashion so that the particular intervention (intact vs. flattened or 6mm vs. 8mm vs. 10mm correction) could not be readily determined. Average and standard deviation of each measure at each intervention stage were calculated to determine the ability of progressively larger lateral calcaneal lengthening to correct each measure toward normal values. An intra-class correlation coefficient was calculated to assess inter-observer variability.

Results

Among three raters, the average naviculo-cuboid overlap was 0.59±0.13 for the intact foot, 0.65±0.12 for the flatfoot model, 0.58±0.14 with the 6mm lateral lengthening, 0.58±0.11 with the 8mm lateral lengthening, and 0.56±0.14 with the 10mm lateral lengthening (Figure 2). The interobserver agreement was excellent for the naviculo-cuboid overlap (ICC = 0.91). The average Meary's angle was -0.3±4.88 for the intact foot, -2.02±5.42 for the flatfoot model, -0.99±5.82 with the 6mm lateral lengthening, 0.38±4.99 with the 8mm lateral lengthening, and 1.51±5.51 with the 10mm lateral lengthening (Figure 3). The interobserver agreement was good for Meary's angle (ICC=0.81). The average talo-navicular coverage angle was 8.7±6.43 for the intact foot, 14.03±10.35 for the flatfoot model, 8.63±6.98 with the 6mm lateral lengthening, 3.74±7.33 with the 8mm lateral lengthening, and 7.83±9.18 with the 10mm lateral lengthening (Figure 4). The interobserver agreement was acceptable for the talo-navicular coverage angle (ICC=0.65).

Discussion

Adult acquired flatfoot is a common condition seen by orthopedic surgeons. We present our technique for creating an acute flatfoot model that may be used in further biomechanical studies, that does not require cyclic loading to create a type IIB deformity. Other cadaveric models for creation of a type IIB flat foot model have been described but require cyclic loading after initial transection to flatten the foot sufficiently to create a Type IIB malalignment [12,13]. Our model preserved the distal midfoot joints at the naviculo-cuneiform and metatarsal-cuneiform level but added transection of the cervical ligament which proved to be the key to allowing AP divergence of the talus and calcaneus; the hallmark of a Type IIB flat foot. In our pilot work, even after excision of the medial and plantar spring ligament, the talus and calcaneus remained well connected. Our described imaging techniques proved to be a reliable way to generate consistent radiographic images by rotating the initial image to specific degrees for the AP view. The advantage of the simulated X-rays was that the talus in particular was much easier to view in total than with usual radiographs. Additionally, using custom designed software to make the measurements for alignment was an effective way to allow measurers to click on bony landmarks with the software then creating the lines and measurements. This may prove to be an effective tool in the future for other X-ray measurements.

We found transection of the cervical ligament, in addition to the spring ligament and ITCL, proved necessary in producing a type IIB flat foot in this cadaveric model. We also report that lateral column lengthening generally restored several standardized measurements towards the foot's normal anatomic position. Lateral column lengthening of 10mm trended towards overcorrection. Our cadaver model and imaging assessment technique can be utilized in future studies evaluating Stage IIB flatfoot conditions.

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Appendix

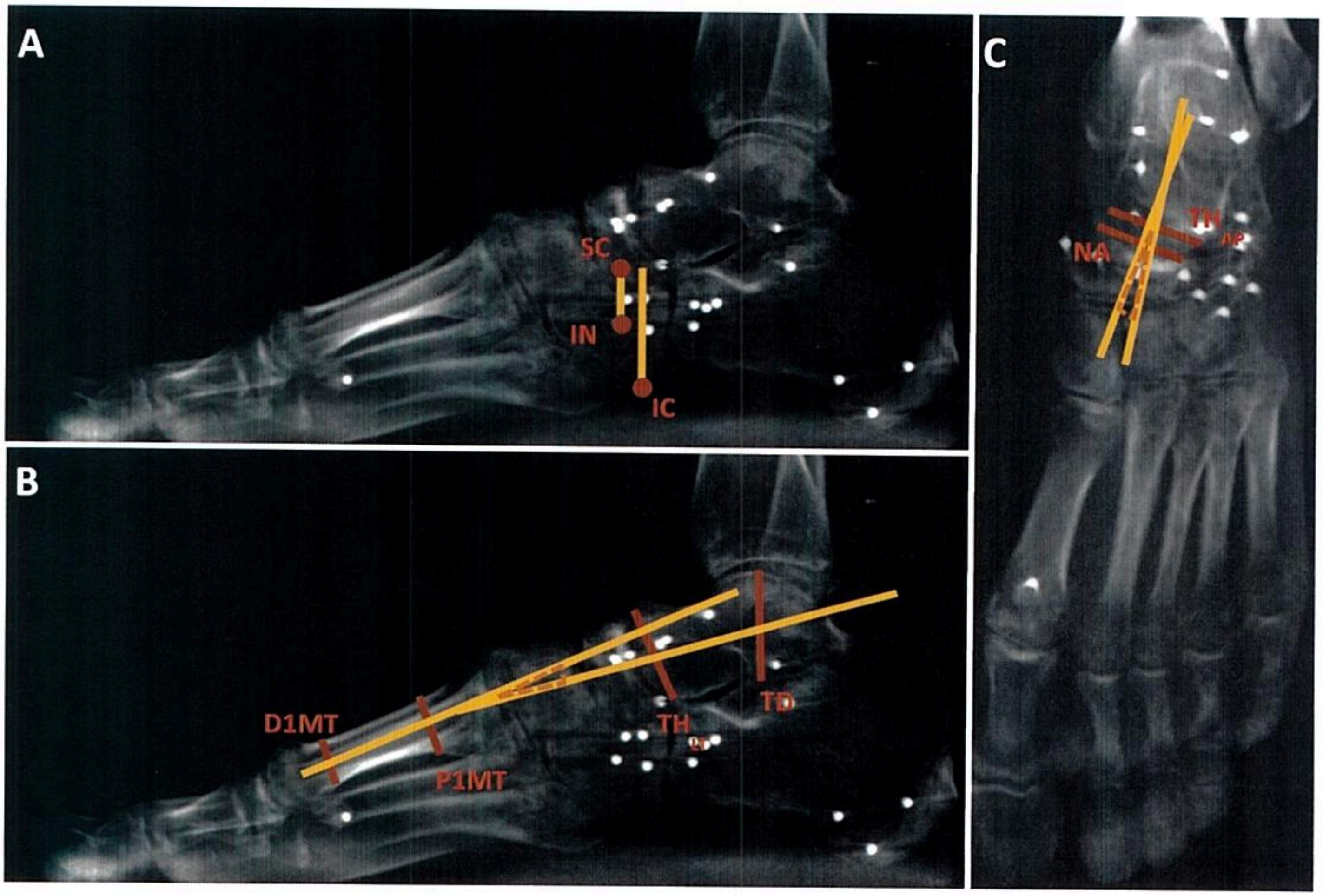


Figure 1. Measurements for naviculo-cuboid overlap (A) Meary's Angle (B), and talonavicular coverage angle (C). Direct measurements made by user are labeled (red) and derived features are shown (yellow).

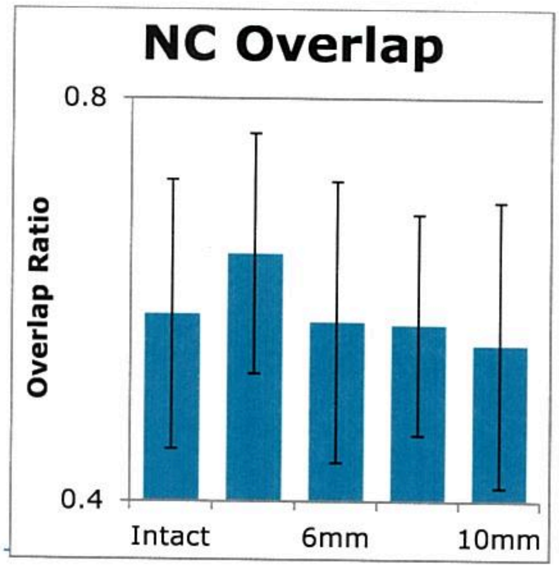


Figure 2. Navicular Cuboid (NC) overlap

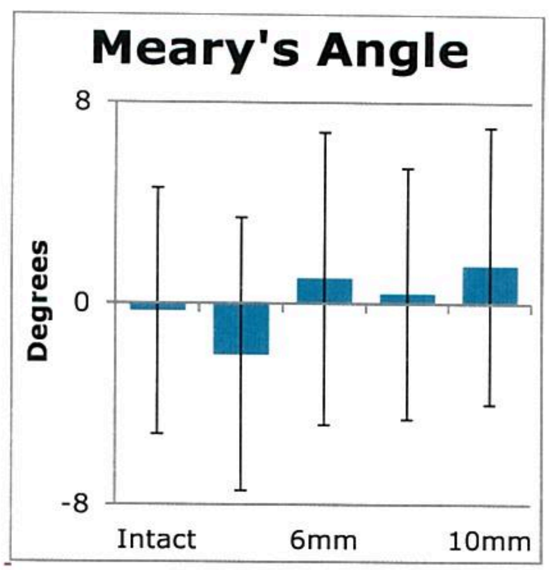


Figure 3. Meary's angle ~~(Lateral Talo-1st Metatarsal angle)~~

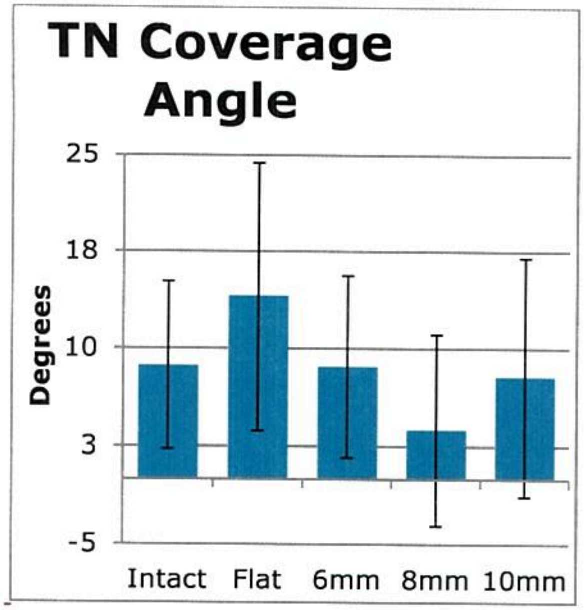
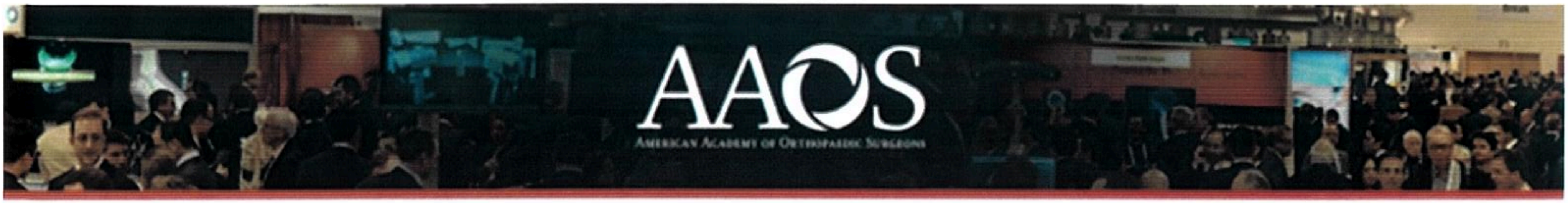


Figure 4. Talar Navicular (TN) coverage angle

Effect of Progressively Larger Lateral Column Lengthening Calcaneal Osteotomy on Radiographic Measurements of Foot Alignment

Christopher Anthony MD, **Ross Schumer MD**, Jessica Goetz PhD,
Phinit Phisitkul MD, John Femino MD



I (and/or my co-authors) have something to disclose.

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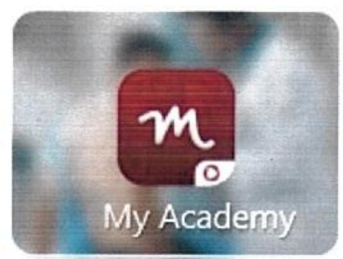

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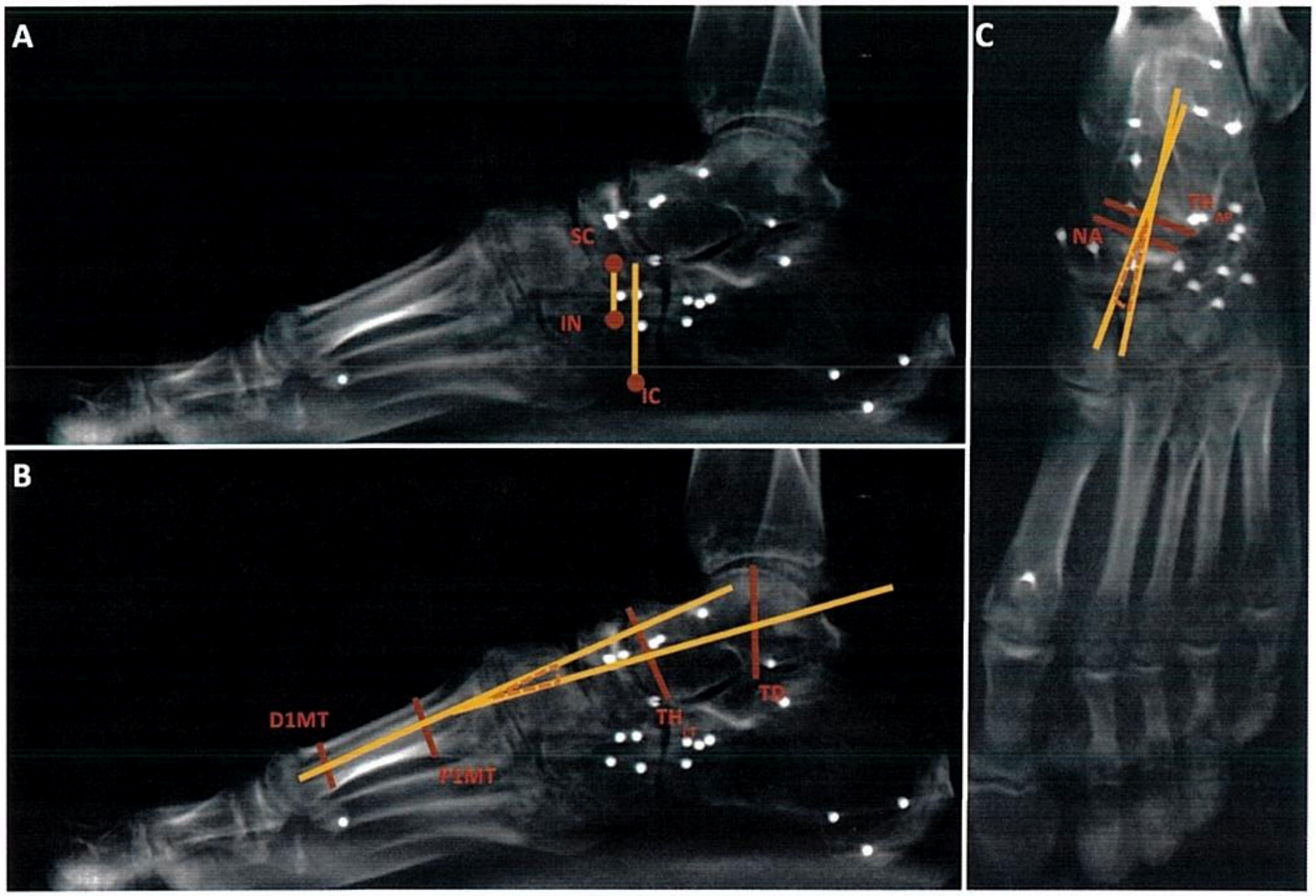
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